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SEMIANNUAL (status) REPORT ~~ON NASA RESEARCH GRANT NSG 249-62~~,

FOR THE PERIOD JULY 1, 1963 - DECEMBER 31, 1963 [Measurement Techniques for the Directional Spectral Intensity of Low Energy Protons, Including the Construction of the Prototype Instrument]

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(NASA Grant NsG-249-62)

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Introduction

The Institute of Geophysics and Planetary Physics of the University of California, Los Angeles, proposes to continue and extend the research work being performed under NASA Research Grant NsG 249-62 for research in Particles and Fields in Space.

This ~~proposal~~ report consists of three parts:

Part I: The latest semiannual progress report on research performed under this grant.

~~Part II: A description of the future research to be performed under a continuation and extension of NASA Research Grant NsG 249-62, and a request for funds required for the performance of this research.~~

~~Part III: A complete description of the experiment on solar and galactic cosmic rays which represents a portion of the future research activity.~~

It is not anticipated that the work under this proposal will require or develop any classified material.

This ~~proposal~~ report has not been submitted to any other Federal agency.

PART I

Semiannual Report on NASA Research Grant NsG 249-62, for the Period July 1, 1963 - December 31, 1963

A. Work Program.

NASA Research Grant NsG 249-62 was awarded to the Institute of Geophysics and Planetary Physics of the University of California at Los Angeles on March 1, 1962 for the support of a space instrument development program. The chief objective of this program was to permit participation of the scientific community at UCLA in the U.S. Space Program. The participation of graduate students at the University has always been a basic part of this research effort.

The report on this grant submitted by Thomas A. Farley to NASA on April 1, 1963 summarized the accomplishments of the first year of the grant. Descriptions of our instrument developments were included. These developments made possible our participation in the Ranger 7-9 program for which we, in a joint experiment with Space Technology Laboratories, Inc., constructed, calibrated, and delivered a prototype and four flight copies of an electron-proton spectrometer. This experiment was cancelled because of a NASA decision to concentrate on the primary mission objectives of Ranger 7-9.

Our proposal for a renewal of the grant was accepted on July 1, 1963, and provided a step-funding arrangement for a three-year period at approximately the same annual rate of expenditure as the original grant. The proposal for the renewal outlined a complete program of research in fields and particles. Our group had been strengthened by the addition of Mr. Paul J. Coleman, Jr., one of the experimenters on the successful Mariner II vehicle. The program of research which was outlined in the proposal included both the preparation for further opportunities within the NASA flight programs, and the reduction and analysis of Mariner II and other related magnetometer data.

This report is a description of the work carried out under this grant since the last report submitted April 1, 1963.

B. Charged Particle Research

The experience gained in the construction and calibration of the Ranger 7-9 electron-proton spectrometers was put to use in the preparation of proposals for an electron-proton spectrometer for both Block IV and Block V of the Ranger spacecraft. These instruments, while modified in some respects as a result of experience gained on the Ranger 7-9 instruments, were designed to make the same measurements by the same techniques which had been employed earlier. The recent cancellation of all of the space-craft for which these two proposals were intended has eliminated any possibility of carrying out this experiment on a Ranger vehicle.

A proposal for essentially the same experiment, with appropriate modifications to meet vehicle requirements, was submitted for the Pioneer spacecraft. This proposal was not accepted. A somewhat different version of the experiment, designed especially for observations in the very interesting region near the boundary of the magnetosphere, was proposed for the IMP-D spacecraft. This proposal has not yet been acted upon.

During the year 1963 an opportunity became available to participate in a Department of Defense space radiation investigation. A dosimetry experiment was conceived by Northrop Space Laboratories to verify certain calculations made by them under an Air Force contract. This experiment required that measurements be made simultaneously of the geophysical environment and of the radiation dose within a spacecraft in the inner zone of trapped radiation.

The Institute of Geophysics designed five instruments for the measurement of the charged particle environment using the techniques developed under the present NASA grant, and employed in flight proposals made to NASA. Prototypes and flight copies of these five instruments were built at Northrop Space Laboratories with funds received from the Air Force. The construction and testing of these instruments took place under the supervision of Charles Benjamin, Mac Chapman, and Thomas Farley of the Institute of Geophysics. The instruments were calibrated using the linear proton accelerator at the University of Southern California, and radioactive sources at UCLA. The delivery of all instruments to the Air Force will be completed by the end of February, 1964. They are presently scheduled to be placed in orbit during the summer of 1964.

The five instruments are as follows:

1. Proton Spectrometer. The instrument consists of a CsI crystal surrounded by an anti-coincidence detector and cemented to a photomultiplier tube. Four channel differential pulse height analysis is employed to measure the energy spectrum and pitch angle distribution of protons from 45 Mev to 100 Mev.

2. ΔE Detector 1. Pulses above a fixed threshold originating in a plastic scintillator are counted. The thickness of the scintillator has been chosen so that only protons from 20-40 Mev give pulses above the threshold. An extremely fast resolving time (30 nanosec) is used to prevent pulse pile-up from electrons.

3. ΔE Detector 2. This instrument is identical to ΔE Detector 1 except that the thickness of scintillator has been chosen so that only protons in the energy range from 10 to 20 Mev are counted.

4. Electron Spectrometer. A small CsI crystal surrounded by an anti-coincidence detector is used to make an eight channel

differential energy spectrum and pitch angle distribution measurement of electrons in the energy range from 350 kev to 5 Mev. A combination shield consisting of beryllium, brass, and lead prevents interference from bremsstrahlung produced in the instrument itself.

5. X-Ray Detector. A thin sliver of CsI cemented to a photomultiplier tube is used to measure the bremsstrahlung produced in an aluminum shield.

We consider our participation in this Air Force program to be a unique opportunity to simultaneously test our designs and obtain useful geophysical data while, at the same time, supporting the nation's efforts in manned space flight. We hope also to answer NASA objections to our flight proposals that our instruments have not been proven in flight. All construction and environmental testing costs in this instance were borne by Northrop Space Laboratories under an Air Force contract.

A wholly different type of charged-particle experiment was designed to measure the flux and relative abundance of ${}_1H^1$, ${}_1H^2$, ${}_1H^3$, ${}_2He^3$, and ${}_2He^4$ which are present in solar and galactic cosmic rays. Measurements made on the casing of Discoverer XVII have shown unexpectedly large concentrations of tritium and helium-3, presumably from solar flare material. These observations are still badly in need of confirmation because of their consequences for certain solar processes. These scientific questions were outlined in a proposal submitted to NASA to make these abundance measurements with our instrument on the Pioneer spacecraft. The proposal was not accepted, apparently because the instrument had not been built and tested in flight. We expect to construct and test flight prototypes of this instrument on any balloons, sounding rockets, and polar orbiting satellites on which we can obtain space.

In order to utilize our capabilities both in charged-particle and magnetic field research, we have designed another experiment to study hydromagnetic waves and their effects on geomagnetically trapped particles. We feel that this simultaneous study of both the fields and particles is likely to be a particularly fruitful technique for further advances in scientific knowledge. The experiment has been designed to take full advantage of the high bit-rate capability of the NASA orbiting geophysical observatories. The data which we propose to obtain can be used to calculate the frequency spectrum of the magnetic and particle disturbances up to several cycles per second. This instrument has been proposed for inclusion on the EGO-3 spacecraft. No decision has yet been made by NASA on this proposal.

Details of the instrumentation and circuits have been included in the proposals for the individual instruments.

In addition to the flight instrumentation research, we have undertaken the computer programming of several useful computations. A program for the theoretical calculation of the ionization energy loss and range of charged particles in any element has been obtained from Professor H. Bichsel of the University of Southern California. This program has been modified so that these calculations may be made correctly for mixtures and compounds as well as pure elements. The modified program will be useful not only in experiment design and spacecraft shielding calculations, but also in a wide range of problems commonly encountered in nuclear physics.

Further work has been done on an original program for the calculation of equatorial pitch angle distributions from measured omnidirectional intensities on a given L shell. We expect to use this program to calculate and study such distributions, using data already published in the literature.

C. Magnetic Fields Research

The purposes of the work under this project are the development of instruments with which to study magnetic and hydromagnetic phenomena in the magnetosphere and beyond, and the analysis of data obtained with such instruments.

Work on this project to date may be divided roughly into four categories:

1. Reduction and analysis of data from the Mariner II magnetometer.

2. Analysis of data from earlier experiments which complement the Mariner II experiment, as well as the reduction and analysis of data concerning phenomena which may be correlated with the variations in the interplanetary magnetic fields observed with Mariner II.

3. Preparations for an experiment to measure the magnetic field of Mars and to study the interplanetary medium during the 1964 Mariner mission.

4. Development of new instruments.

In the first category, the major part of our work has been devoted to the preparation and execution of computer programs which are used in the reduction and analysis of the data from the Mariner II magnetometer experiment. Examples of such programs follow: (1) A program which involves corrections for the effects of the solar panel failure. This failure added several complicating modes of instrument operation. (2) A machine program, already completed, which generates histograms for various quantities of interest which may be obtained from the magnetometer data, thus providing an immediate graphical representation which indicates the distribution of any such quantity over the quarter-million sets of measurements. (3) A completed program which provides the orientation of the tangential component of the magnetic field based upon the trajectory and orientation data for the flight.

(4) A program which corrects for the rolling motion of the spacecraft during the "roll-period" of the flight.

The rest of the work in this first category has involved the reduction of preflight calibration and test data as well as flight data from which to obtain necessary corrections to the measured field values. To date, we have completed the corrections required for the changes in the measured field which were produced as a result of the motion of the antenna hinge. Also, we have started a program with which to process magnetometer data obtained during periods marked by anomalous temperature readings.

As you are aware, only one of the experimenters on the Mariner II magnetometer, P.J. Coleman, Jr., is at UCLA. Thus, the work at UCLA in this first category supplements work at the Jet Propulsion Laboratory and Ames Research Center which is being performed simultaneously under the direction of the other three co-experimenters. In this way we hope to facilitate the completion of this rather formidable data reduction task.

It should be mentioned that a substantial portion of the work at UCLA in this first category was performed by individuals who were supported under NASA research grant NsG 237-62. The reasons were first, that this work was a new project and was therefore set-up, as are most new projects, under NsG 237-62 and, second, that the grant NsG 249-62 could not have supported the entire effort.

In the second category, most of the work has involved the application of computer techniques of analysis to the measurements of magnetic fields which were obtained with Pioneer V in 1960. Pioneer V and Mariner II have provided the only direct measurements of the interplanetary fields (with the exception of the relatively few measurements from Soviet spacecraft). More specifically, the comparison of such measurements obtained during different portions of the solar cycle should be valuable. Further, since the Pioneer V instrument provided relatively high sampling rates during certain periods of the flight, a careful analysis of the spectra of observed interplanetary field variations should allow us to estimate whether the Mariner sampling rate will be adequate for similar analyses. In addition, filter and correlation programs which will be applied to Mariner II data and to other data, such as the K_p indices, recorded during the flight have been programmed and applied to sample sections of these data. Also, studies of events recorded by certain of the other instruments aboard Mariner II, and possibly related to events recorded on the magnetometer, have been started in collaboration with the experimenters involved.

In the third category, preparations for magnetometer experiment for the 1964 Mariner mission to Mars, our work has included monitoring the magnetometer development and fabrication at Texas Instruments, Inc., in collaboration with the co-experimenters and with JPL personnel. In addition, we have collaborated with the co-experimenters and with Mariner Project Personnel at JPL to establish final design requirements for the magnetometer and the ground support equipment required in the pre-launch tests, and to establish data handling requirements, calibration procedures, and test procedures.

In the fourth category, instrument development, we have undertaken a feasibility study of a rocket magnetometer which would discriminate between the field changes produced by hydromagnetic disturbances and those produced by both the motion of the instrument package in the geomagnetic field and by magnetic noise generated in the package itself. This work is part of a project of experimental studies in magnetohydrodynamics, the remainder of which was supported with funds from NsG 237.

D. Student Participation

A basic purpose of our research is to make it possible for students to participate in scientific experiments within the rapidly developing field of space science. The work performed under this grant has provided an opportunity for participation in advanced research by five UCLA graduate students listed below:

1. Daryoush Aalami

   Mr. Aalami is a graduate student in the Engineering Department. He has designed, constructed, and tested a prototype power supply and a specialized calibration pulse generator for the instruments which have been developed under this grant. Mr. Aalami expects to write a Ph.D. thesis on some aspect of electronic instrumentation developed within our laboratory.

2. Mac C. Chapman

Mr. Chapman is a graduate student in the space science program of the Geophysics Interdepartmental Curriculum. He has participated in the design of the sensors for the proposed experiments, as well as in the calibration and check-out of the breadboards. Mr. Chapman hopes to use the results of future flights for his thesis research.

3. Paul J. Coleman, Jr.

Mr. Coleman is a graduate student in the space science program of the Geophysics Interdepartmental Curriculum. He is presently involved in the reduction and analysis of data from the Mariner II magnetometer experiment, as well as preparations for a magnetometer experiment on the scheduled Mariner C spacecraft. Mr. Coleman expects to incorporate some of the results of this work in a Ph.D. thesis.

4. Mr. Neil Eskind

Mr. Eskind is a graduate student in the Engineering Department. He is investigating the detection of low-energy beta radiation with solid state radiation detectors, and is interested also in the collection and return of micrometeorite material from spacecraft. He anticipates a Ph.D. thesis in one of these areas of research.

5. Alan J. Eskovitz

As a part of the work in the development of rocket-borne magnetometers, Alan Eskovitz, graduate student in engineering, has undertaken a detailed study of the characteristics of nonlinear amplifiers which have been employed in previous experiments. In particular, the response of such amplifiers to signals with various types of power spectra is to be determined.

All of the registered graduate students whose support is provided by this grant are employed as research assistants in classifications normally open to graduate students under long-established UCLA regulations. Their rates of pay are established by the Regents of the University at levels appropriate to their classifications. A considerable effort is made to assign research tasks which are of special interest to the student, but the tasks themselves are not necessarily related directly or indirectly to the thesis research which the student may eventually perform.

D. Publications

Scientific articles of the investigators on this grant which have appeared in print or are being prepared for publication since the last semi-annual report include the following:

Smith, E.J., L. Davis, Jr., P.J. Coleman, Jr., and C.P. Sonett, Mariner II magnetic field measurements near Venus, Science, 139, 909, 1963.

Farley, T.A., The growth of our knowledge of the earth's outer radiation belt, Rev. of Geophys., 1, 3-34, 1963.

Coleman, P.J., Jr., Characteristics of the region of interaction between the interplanetary plasma and the geomagnetic field: Pioneer 5, to be submitted to J. Geophys. Res., 1964.

Farley, T.A., The Van Allen radiation belts, in preparation for the Encyclopedia of Earth Sciences.